## NASA/TM-2000-209891, Vol. 23



# Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and David E. Knapp, Editors

## Volume 23 BOREAS HYD-3 Subcanopy Meteorological Measurements

J.P. Hardy and R.E. Davis

National Aeronautics and Space Administration

**Goddard Space Flight Center** Greenbelt, Maryland 20771

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# Volume 23 BOREAS HYD-3 Subcanopy Meteorological Measurements

Janet P. Hardy and Robert E. Davis U.S. Army Cold Regions Research and Engineering Laboratory (CRREL)

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## **BOREAS HYD-3 Subcanopy Meteorological Measurements**

Janet P. Hardy, Robert E. Davis

## Summary

The BOREAS HYD-3 team collected several data sets related to the hydrology of forested areas. This data set includes measurements of wind speed and direction; air temperature; relative humidity; and canopy, trunk, and snow surface temperatures within three forest types. The data were collected in the SSA-OJP (1994) and SSA-OBS and SSA-OA (1996). Measurements were taken for 3 days in 1994 and 4 days at each site in 1996. These measurements were intended to be short term to allow the relationship between subcanopy measurements and those collected above the forest canopy to be determined. The subcanopy estimates of wind speed were used in a snow melt model to help predict the timing of snow ablation. The data are available in tabular ASCII files.

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## 1. Data Set Overview

## 1.1 Data Set Identification

BOREAS HYD-03 Subcanopy Meteorological Measurements

## 1.2 Data Set Introduction

This data set includes measurements of wind speed and direction within one aspen and two conifer forests. The data were collected in the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) Old Jack Pine (OJP) (1994) and the SSA-Old Black Spruce (OBS) and SSA-Old Aspen (OA) (1996). Measurements were taken for only 3 days in 1994 and 4 days at each site in 1996. An RM Young wind monitor, a Vaisala temperature and relative humidity (temp/RH) probe, and infrared thermometers were used to measure canopy, trunk, and snow surface temperatures. The wind monitor and temp/RH probe were mounted 2 meters above the snow surface, and a Campbell Scientific CR10 data logger was used for all data collection.

## 1.3 Objective/Purpose

This study was undertaken to predict spatial distributions of energy transfer and snow properties important to the hydrology, remote sensing signatures, and transmissivity of gases through the snow and their relation to forests in boreal ecosystems. The purpose of these measurements was to allow the relationship between subcanopy measurements and those collected above the forest canopy to be determined. Once they were determined, the above-canopy measurements were modified to estimate the subcanopy measurements. The subcanopy estimates of wind speed were used in the snow melt model to help predict the timing of snow ablation.

## 1.4 Summary of Parameters

Parameters measured with respect to this documentation are canopy wind speed and direction, air temperature, relative humidity, stem temperature, and snow surface temperature.

## 1.5 Discussion

During the Focused Field Campaign-Winter (FFC-W) in 1994 and 1996, meteorological parameters were measured at 2 m height in SSA-OJP (1994) and SSA-OBS and OA (1996). The data were collected for only 3 days (1994) or 4 days (1996) and are intended for comparison with above-canopy meteorological data. The data are averages of several measurements over a 10-min. (1994) and 1-min. (1996) interval. An RM Young wind monitor, a Vaisala temp/RH probe mounted 2 meters above the snow surface, and a Campbell Scientific CR10 data logger were used for data collection. Infrared thermometers were aimed at tree canopies, trunks, and the snow surface to provide measurements. The sensors and the data logger system are among the best available. Because of the nature of the forest canopy, wind speeds were VERY low, and in many cases below the threshold value of the sensor (1.0 m/s). For this reason, the data are somewhat questionable as to the absolute magnitude of the wind, but provide good relative information as to the timing and magnitude of wind events. The wind direction data are believed to be as accurate as the manufacturer's specifications.

#### 1.6 Related Data Sets

BOREAS TF-02 SSA-OA Tower Flux Data BOREAS TF-01 SSA-OA Tower Flux Data BOREAS TF-05 SSA-OJP Tower Flux Data BOREAS TF-09 SSA-OBS Tower Flux Data BOREAS HYD-03 Subcanopy Incoming Solar Radiation Data

## 2. Investigator(s)

## 2.1 Investigator(s) Name and Title

Robert E. Davis, Research Physical Scientist U.S. Army Cold Regions Research and Engineering Laboratory (CRREL)

#### 2.2 Title of Investigation

Distributed Energy Transfer Modeling in Snow and Soil for Boreal Ecosystems

## 2.3 Contact Information

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Dr. Robert E. Davis U.S. Army CRREL 72 Lyme Road Hanover, NH 03775-1290 (603) 646-4219 (603) 646-4278 (fax) bert@crrel.usace.army.mil

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## 3. Theory of Measurements

The meteorological data were collected to investigate the effect of forest structure on the within-canopy winds, temperatures, and humidity. Data were compared with those collected from BOREAS flux towers at heights above the canopy to assist in developing a relationship between subcanopy and above-canopy winds in species of the boreal forest. This understanding is essential in modeling snow ablation in the forest.

## 4. Equipment

## 4.1 Sensor/Instrument Description

## 4.1.1 Collection Environment

All data were collected during winter campaigns; therefore, the instruments were subjected to cold temperatures. Days were relatively clear and cold, and forest winds were light during the collection period. Cold temperatures would not affect the sensors nor the data quality, but low wind speeds (below the 1.0 m/s threshold) affect the quality of wind data.

#### 4.1.2 Source/Platform

2-meter tower in forest.

#### 4.1.3 Source/Platform Mission Objectives

The objective was to measure within-canopy winds, temperature, and humidity.

## 4.1.4 Key Variables

Within Canopy:

Wind speed and wind direction, air temperature, relative humidity, trunk and snow surface temperature.

## 4.1.5 Principles of Operation

Wind Monitor: The wind monitor measures horizontal wind speed and direction. Propeller rotation produces an AC signal with frequency proportional to wind speed. The AC signal is monitored and data are processed by a Campbell data logger. Wind direction is measured by applying constant voltage to a potentiometer; the output signal is an analog voltage directly proportional to azimuth angle.

Temp/RH Probe: Sensors within the probe measure the air temperature and relative humidity according to specifications discussed below.

Infrared Thermometers: An infrared thermometer measures radiant energy. Temperature readings are taken with an infrared thermometer by aiming the infrared temperature transducer at the desired object. The infrared thermometers used in this study have fields-of-view (FOV) of 15° and 4°. It was important in orienting the temperature sensor that the entire FOV was filled with the desired object.

Infrared Radiometers: The Eppley Precision Infrared Radiometer (PIR) (pyrgeometer) measures incoming longwave radiation of wavelengths between 4  $\mu$ m and 50  $\mu$ m. This instrument is believed to be the most accurate radiometer produced commercially for the measurement of longwave radiation. The pyrgeometer measures the exchange of radiation between a horizontal blackened surface (i.e., the detector) and the target viewed (i.e., sky or ground). The signal is monitored and data are processed on a Campbell Scientific data logger (CR10).

## 4.1.6 Sensor/Instrument Measurement Geometry

Wind Monitor: This sensor was located on top of a tower, 2 meters above the snow surface. The sensor was oriented to true south in 1994 during installation, except in 1996, when the sensor was oriented to magnetic south.

Temp/RH Probe: This sensor with radiation shield was mounted on the same tower approximately 2 m above the snow surface.

Infrared Thermometer: The infrared thermometers used to measure canopy and trunk temperatures were mounted on tripods, approximately 1 m above the snow surface, and the sensor was pointed at the west or east side of the tree trunk. For infrared thermometers pointing at the canopy, care was taken to find a thick part of the canopy and to avoid measuring any background. The radiometer used for snow surface temperature measurements was similarly mounted on a tripod and aimed at the snow surface.

Infrared Radiometers (pyrgeometers): Sensors were located on the snow surface using either a foam block (1994) or the radiometer case (1996) for support on the snow surface. Sensors were leveled daily using the bubble level mounted on the radiometer base.

## 4.1.7 Manufacturer of Sensor/Instrument

Wind Monitor: Manufacturer: R.M. Young Company Distributor: Campbell Scientific Inc. 815 W. 1800 N. Logan, Utah 84321-1784 (801) 753-2342

Vaisala Temp/RH Probe, Model HMP35C: Manufacturer: Vaisala, Inc., Woburn, MA Distributor: Campbell Scientific, Inc. 815 W. 1800 N. Logan, UT 84321-1784 (801) 753-2342 Everest Series 4000 Infrared Temperature Transducer (low temperature model)

Manufacturer: Everest Interscience, Inc.

Everest Interscience, Inc.

1120 S. Raymond Fullerton, CA 92631

(800) 422-4342

Eppley Precision Infrared Radiometer (pyrgeometer)

Manufacturer: Eppley Laboratory, Inc.

12 Sheffield Ave. Newport, RI 02840 (401) 847-1020

## 4.2 Calibration

- Wind Monitor: The sensor was oriented to true south during installation, except in 1996 when the sensor was oriented to magnetic south. A Brunton compass was used in the orientation of the sensor. This sensor is better oriented to the south because of a 5° "dead zone" between 355° and 360°.
- Temp/RH probe: Probes are calibrated to specifications of +/- 3% RH. Recalibration is performed at room temperature at 20%, 50%, and 85% RH.
- Infrared Thermometers: Infrared temperature transducers were calibrated by Everest upon purchase. Laboratory tests were conducted periodically for comparison of sensors and to provide confidence in the data.
- Infrared Radiometers (pyrgeometers): All pyranometers were new in 1994 and were therefore factory calibrated, with reference to Eppley primary standards, just prior to deployment in the field in 1994.

## 4.2.1 Specifications

Wind Monitor: The RM Young sensor has a 5°, wind direction, "dead zone" between 355° and 360°.

Temp/RH Probe: The probe is used only with a white radiation shield obtained from the distributor.

Infrared Thermometers:

Spectral pass-band = 8 mm to 14 mm.

emmissivity preset at factory at 0.98.

FOV =  $4^{\circ}$  and  $15^{\circ}$ .

Operating distance = 0.2 m to 1,000 ft focus.

Optical configuration = 35-mm precision corrected refractive optics.

Infrared Radiometers (pyrgeometers):

Sensitivity =  $4 \mu Volts per Watt per m^2$ 

Receiver: circular 1 cm<sup>2</sup> in area.

Linearity =  $\pm -1\%$ , 0 to 700 Watts per m<sup>2</sup>

Cosine response = better than 5% from normalization, insignificant for a

diffuse source.

## **4.2.1.1 Tolerance**

Wind Speed:

Accuracy =  $\pm - 0.3$  m/s.

Wind speed threshold sensitivity = 1.0 m/s

(the wind speed data are not accurate below 1.0 m/s).

Wind Direction:

Accuracy =  $\pm -3.0^{\circ}$  (<1%).

Temp/RH probe:

RH range = 0-100%.

Temperature range: -35 °C to 50 °C.

Accuracy at temperatures between  $-24^{\circ}$ C and  $48^{\circ}$ C = <+/-0.1°C.

Accuracy at temperature of  $-40^{\circ}\text{C} = +/-0.5^{\circ}\text{C}$ .

Infrared thermometers:

Temperature range = -25 °C to 75 °C.

Accuracy =  $\pm -0.5$  °C. Resolution =  $\pm -0.1$  °C.

Infrared radiometers:

Temperature dependance =  $\pm$  2%,  $\pm$  20 °C to 40 °C.

## 4.2.2 Frequency of Calibration

- Wind Monitor: The RM Young wind sensor was fully calibrated when purchased on 19-Jan-1994 and has not been recalibrated since purchase. The RM Young manual provides details on calibrating the sensor.
- Temp/RH Probe: On a regular basis and prior to field use, several Vaisala Temp/RH probes are run adjacent to each other and concurrently to compare precision with other sensors. Probes that appear to be imprecise are either returned to the manufacturer for recalibration, or retired. Only probes with a high degree of precision are used in the field. This instrument was bought on 30-Jun-1994.
- Infrared Thermometers: Factory calibrated upon initial purchase.
  - Infrared thermometer #1: bought in 1994.
  - Infrared thermometer #2: bought in 1994.
  - Infrared thermometer #3: bought in 1991, recalibrated 1992.
  - Infrared thermometer #3 was returned to manufacturer 1 year after purchase to improve its cold weather handling and recalibrated, since it is an older model. Prior to field use we conducted laboratory tests using 0 °C ice baths to provide confidence in instrument.
- Infrared Radiometers (pyrgeometers): The manufacturer of the pyranometers recommends calibration after a cumulative use of 2 years. These radiometers were new at the beginning of the FFC-W 1994 and therefore are well within calibration. Because they have been used for only ~20 days per year and stored in their dark case when not in use, the calibration should be valid for several years at the current rate of usage.

## 4.2.3 Other Calibration Information

Available from the manufacturer.

## 5. Data Acquisition Methods

All sensors were installed according to manufacturer procedures. Data were recorded on a Campbell Scientific data logger. The data logger was programmed to measure parameters every minute and output 10-minute averages (1994) and measure parameters every second and output 1-minute averages (1996).

## 6. Observations

## **6.1 Data Notes**

None given.

## **6.2 Field Notes**

Wind direction oriented to true south in 1994. Wind direction oriented to magnetic south in 1996.

## 7. Data Description

## 7.1 Spatial Characteristics

## 7.1.1 Spatial Coverage

Site	Year	Longitude	Latitude
SSA-OJP	1994	104.69203W	53.91634N
SSA-OBS	1996	105.11779W	53.98718N
SSA-OA	1996	106.19779W	53.6289N

All measurements were made within 50 meters of flux tower sites.

## 7.1.2 Spatial Coverage Map

Not available.

## 7.1.3 Spatial Resolution

Point data, 2-meter height in forest.

## 7.1.4 Projection

All latitude/longitude locations are given in the North American Datum of 1983 (NAD83).

## 7.1.5 Grid Description

Not applicable.

## 7.2 Temporal Characteristics

## 7.2.1 Temporal Coverage

FFC-W 1994: 06-Feb-1994 - 10-Feb-1994

SSA-OJP: 06-Feb-1994 - 10-Feb-1994 SSA-OBS: 28-Feb-1996 - 03-Mar-1996 SSA-OA: 04-Mar-1996 - 08-Mar-1996

## 7.2.2 Temporal Coverage Map

SSA-OJP: 06-Feb-1994 - 10-Feb-1994 SSA-OBS: 28-Feb-1996 - 03-Mar-1996 SSA-OA: 04-Mar-1996 - 08-Mar-1996

## 7.2.3 Temporal Resolution

10-minute averages (1994), 1-minute averages (1996)

## 7.3 Data Characteristics

## 7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

Column Name SITE\_NAME SUB SITE DATE\_OBS TIME OBS MEAN\_DOWN\_THERMAL\_RAD\_1 MEAN\_DOWN\_THERMAL\_RAD\_2 MEAN WIND SPEED 2M MEAN\_WIND\_SPEED\_VECTOR\_MAG\_2M MEAN\_WIND\_VECTOR\_DIR\_2M SDEV\_WIND\_DIR\_2M CANOPY\_TEMP\_1 CANOPY\_TEMP\_2 TRUNK TEMP 1 TRUNK\_TEMP\_2 AIR\_TEMP\_2M SNOW\_SURF\_TEMP REL\_HUM\_2M CRTFCN CODE REVISION\_DATE

## 7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) when the data were collected.
MEAN_DOWN_THERMAL_RAD_1	The mean thermal radiation to the surface.
MEAN_DOWN_THERMAL_RAD_2	The mean thermal radiation to the surface.
MEAN_WIND_SPEED_2M	The mean wind speed that was measured at 2 meters above the ground.
MEAN_WIND_SPEED_VECTOR_MAG_2M	The mean wind vector magnitude at 2 meters above the ground.

MEAN\_WIND\_VECTOR\_DIR\_2M The mean wind direction at 2 meters above the ground. The standard deviation of the wind direction at SDEV WIND DIR 2M 2 meters above the ground. CANOPY TEMP 1 The temperature of the canopy from sensor 1. CANOPY\_TEMP\_2 The temperature of the canopy from sensor 2. TRUNK\_TEMP\_1 The temperature of tree trunk 1 at the site. The temperature of tree trunk 2 at the site. TRUNK\_TEMP\_2 AIR TEMP 2M The air temperature at 2 meters above the ground. SNOW\_SURF\_TEMP The temperature of the snow surface. REL HUM 2M The relative humidity at 2 meters above ground. CRTFCN\_CODE The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable). The most recent date when the information in the REVISION DATE referenced data base table record was revised.

## 7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
MEAN_DOWN_THERMAL_RAD_1	[Watts][meter^-2]
MEAN_DOWN_THERMAL_RAD_2	[Watts][meter^-2]
MEAN_WIND_SPEED_2M	[meters][second^-1]
MEAN_WIND_SPEED_VECTOR_MAG	[meters][second^-1]
MEAN_WIND_VECTOR_DIR_2M	[degrees]
SDEV_WIND_DIR_2M	[degrees]
CANOPY_TEMP_1	[degrees Celsius]
CANOPY_TEMP_2	[degrees Celsius]
TRUNK_TEMP_1	[degrees Celsius]
TRUNK_TEMP_2	[degrees Celsius]
AIR_TEMP_2M	[degrees Celsius]
SNOW_SURF_TEMP	[degrees Celsius]
REL_HUM_2M	[percent]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

#### 7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS]
SUB_SITE	[Assigned by BORIS]
DATE_OBS	[Supplied by Investigator]
TIME_OBS	[Supplied by Investigator]
MEAN_DOWN_THERMAL_RAD_1	[Supplied by Investigator]
MEAN_DOWN_THERMAL_RAD_2	[Supplied by Investigator]

MEAN_WIND_SPEED_2M	[Supplied b	oy Investigator]
MEAN_WIND_SPEED_VECTOR_MAG	[Supplied b	oy Investigator]
MEAN_WIND_VECTOR_DIR_2M	[Supplied b	oy Investigator]
SDEV_WIND_DIR_2M	[Supplied b	oy Investigator]
CANOPY_TEMP_1	[Supplied b	oy Investigator]
CANOPY_TEMP_2	[Supplied k	oy Investigator]
TRUNK_TEMP_1	[Supplied k	oy Investigator]
TRUNK_TEMP_2	[Supplied k	oy Investigator]
AIR_TEMP_2M	[Supplied k	oy Investigator]
SNOW_SURF_TEMP	[Supplied b	oy Investigator]
REL_HUM_2M	[Supplied b	oy Investigator]
CRTFCN_CODE	[Assigned b	by BORIS]
REVISION_DATE	[Assigned k	by BORIS]

## 7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

	Minimum	Maximum	Missng	Unrel	Below	Data
_	Data	Data	Data	Data	Detect	Not
Column Name	Value	Value 	Value 	Value 	Limit	Cllctd
SITE_NAME	SSA-90A-FLXTR	SSA-OJP-FLXTR	None	None	None	None
SUB_SITE	HYD03-SCM01	HYD03-SCM01	None	None	None	None
DATE_OBS	06-FEB-94	08-MAR-96	None	None	None	None
TIME_OBS	0	2359	None	None	None	None
MEAN_DOWN_THERMAL_	176.1	264.5	-999	None	None	Blank
RAD_1						
MEAN_DOWN_THERMAL_	176.2	315.1	-999	None	None	Blank
RAD_2						
MEAN_WIND_SPEED_2M	0	1.766	-999	None	None	Blank
MEAN_WIND_SPEED_	0	1.581	-999	None	None	Blank
VECTOR_MAG_2M						
MEAN_WIND_VECTOR_DIR	_ 0	360	-999	None	None	Blank
2M						
SDEV_WIND_DIR_2M	0	81	-999	None	None	Blank
CANOPY_TEMP_1	-27.2	-3.9	-999	None	None	Blank
CANOPY_TEMP_2	-27.4	-3	-999	None	None	Blank
TRUNK_TEMP_1	-27.2	-1.8	-999	None	None	Blank
TRUNK_TEMP_2	-27.4	-4.9	None	None	None	Blank
AIR_TEMP_2M	-29.5	-6.3	-999	None	None	Blank
SNOW_SURF_TEMP	-17.4	-8.3	-999	None	None	Blank
REL_HUM_2M	28	86.2	-999	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	18-JUN-97	18-JUN-97	None	None	None	None

Minimum Data Value -- The minimum value found in the column.

Maximum Data Value -- The maximum value found in the column.

Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.

Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be unreliable by the analysis personnel.

```
Below Detect Limit -- The value that indicates parameter values below the
                      instruments detection limits. This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the analysis personnel determined
                      that the parameter value was below the detection
                      limit of the instrumentation.
Data Not Cllctd
                   -- This value indicates that no attempt was made to
                      determine the parameter value. This usually
                      indicates that BORIS combined several similar but
                      not identical data sets into the same data base table
                      but this particular science team did not
                      measure that parameter.
Blank -- Indicates that blank spaces are used to denote that type of value.
N/A -- Indicates that the value is not applicable to the respective column.
None -- Indicates that no values of that sort were found in the column.
```

## 7.4 Sample Data Record

The following are wrapped versions of data records from a sample data file on the CD-ROM.

```
SITE_NAME, SUB_SITE, DATE_OBS, TIME_OBS, MEAN_DOWN_THERMAL_RAD_1,
MEAN_DOWN_THERMAL_RAD_2, MEAN_WIND_SPEED_2M, MEAN_WIND_SPEED_VECTOR_MAG_2M,
MEAN_WIND_VECTOR_DIR_2M, SDEV_WIND_DIR_2M, CANOPY_TEMP_1, CANOPY_TEMP_2,
TRUNK_TEMP_1, TRUNK_TEMP_2, AIR_TEMP_2M, SNOW_SURF_TEMP, REL_HUM_2M,
CRTFCN_CODE, REVISION_DATE
'SSA-9OA-FLXTR', 'HYDO3-SCM01', 04-MAR-96, 2010, 226.4, 227.0, .938, .907, 34.25, 14.55,,
,-21.7,-16.8,-17.9,-999.0,59.2, 'CPI', 18-JUN-97
'SSA-9OA-FLXTR', 'HYDO3-SCM01', 04-MAR-96, 2011, 226.3, 226.9, .89, .831, 42.95, 20.8,,,-
22.0,-16.9,-18.1,-999.0,59.4, 'CPI', 18-JUN-97
```

## 8. Data Organization

## 8.1 Data Granularity

The smallest amount of data that can be ordered from this data set is a day's worth of data for a given site.

#### **8.2 Data Format(s)**

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

## 9. Data Manipulations

## 9.1 Formulae

Not applicable.

## 9.1.1 Derivation Techniques and Algorithms

Not applicable.

## 9.2 Data Processing Sequence

Not applicable.

## 9.2.1 Processing Steps

Not applicable.

## 9.2.2 Processing Changes

Not applicable.

#### 9.3 Calculations

## 9.3.1 Special Corrections/Adjustments

Infrared thermometer #3 did not provide reliable data when air temperatures were below -15 °C, so all the bad thermal data were replaced with -999. Reliable data from infrared radiometer #3 were obtained only when air temperatures were greater than -15 °C. Infrared thermometer #3 was used to collect trunk temperature at the SSA-OBS and snow surface temperature at the SSA-OA.

It is important to note that the wind direction sensor was oriented to true south during installation, except in 1996 when the sensor was oriented to magnetic south. A Brunton compass was used in the orientation of the sensor. This sensor is better oriented to the south because of a 5° "dead zone" between 355° and 360°.

Any wind speed data with a value less than 0.0 were changed to 0.

#### 9.3.2 Calculated Variables

None.

## 9.4 Graphs and Plots

None.

## 10. Errors

#### 10.1 Sources of Error

Assuming an operative instrument, the primary source of error for the wind direction sensor is in the initial installation and the ability of the installer to accurately orient the monitor.

## **10.2 Quality Assessment**

## 10.2.1 Data Validation by Source

Wind, air temperature, and relative humidity data were compared with Saskatchewan Research Council (SRC) data measured above the canopy.

## 10.2.2 Confidence Level/Accuracy Judgment

Great care was taken to orient the wind monitor during installation. Quantification of the accuracy beyond the manufacturer's accuracy is difficult. The wind speed data are all below the threshold value of 1.0 m/s; therefore, the data are not absolute. These wind speed data are useful only for determining

the occurrence of wind events. Similarly, wind direction data are also useful only during the wind events because wind direction data under calm conditions are meaningless. Temperature and relative humidity data are as good as the accuracy of the instrument. Canopy, trunk, and snow surface temperature data quality are limited by the accuracy of the infrared thermometer.

#### **10.2.3 Measurement Error for Parameters**

Not available.

## 10.2.4 Additional Quality Assessments

Not available.

## 10.2.5 Data Verification by Data Center

Data that were loaded into the data tables were spot checked against the original ASCII data that were submitted to check for data loading errors.

## 11. Notes

#### 11.1 Limitations of the Data

The wind speed data are all below the threshold value of 1.0 m/s; therefore, the data are not absolute. These wind speed data are useful only for determining the occurrence of wind events. Similarly, wind direction data are also useful only during the wind events because wind direction data under calm conditions are meaningless.

#### 11.2 Known Problems with the Data

Infrared thermometer #3 did not provide reliable data when air temperatures were below -15 °C, so all the bad thermal data were replaced with -999. Reliable data from infrared radiometer #3 were obtained only when air temperatures were greater than -15 °C. Infrared thermometer #3 is the third one in the data field.

## 11.3 Usage Guidance

The wind speed data are all below the threshold value of 1.0 m/s; therefore, the data are not absolute. These wind speed data are useful only for determining the occurrence of wind events. Similarly, wind direction data are also useful only during the wind events because wind direction data under calm conditions are meaningless.

It is important to note that the wind direction sensor was oriented to true south during installation, except in 1996 when the sensor was oriented to magnetic south. A Brunton compass was used in the orientation of the sensor. This sensor is better oriented to the south because of a 5° "dead zone" between 355° and 360°.

#### 11.4 Other Relevant Information

Not available.

## 12. Application of the Data Set

This data set can provide information on the timing and relative magnitude of wind events in the forest and an approximate direction of wind. The data set, in conjunction with data from the tower, also provides insight into the relationship between above-canopy and below-canopy meteorology.

## 13. Future Modifications and Plans

None.

## 14. Software

## 14.1 Software Description

An undetermined spreadsheet program was used to organize the data.

## 14.2 Software Access

None given.

## 15. Data Access

The subcanopy meteorological measurement data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

#### 15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services Oak Ridge National Laboratory P.O. Box 2008 MS-6407 Oak Ridge, TN 37831-6407 Phone: (423) 241-3952

Phone: (423) 241-3952 Fax: (423) 574-4665

E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

## 15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/ [Internet Link].

## 15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

## 15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

## 16. Output Products and Availability

## 16.1 Tape Products

None.

## 16.2 Film Products

None.

#### 16.3 Other Products

These data are available on the BOREAS CD-ROM series.

## 17. References

## 17.1 Platform/Sensor/Instrument/Data Processing Documentation

Data logger and temp/RH probe: manual available from manufacturer/distributor: Campbell Scientific, Inc. 815 W. 1800 N. Logan, UT 84321-1784 (801) 753-2342

Infrared thermometer manual available from manufacturer: Everest Interscience, Inc. 1120 S. Raymond Fullerton, CA 92631 (800) 422-4342

Wind sensor: manual available from manufacturer: R.M. Young Company 2801 Aero-Park Drive Traverse City, MI 49684 (616) 946-3980

## 17.2 Journal Articles and Study Reports

Davis, R.E., C. Woodcock, and J.P. Hardy. 1996. Toward spatially distributed modeling of snow in the boreal forest. Eos Transactions, AGU 1995 Fall Meeting, Abstract, p. 218.

Davis, R.E., J.P. Hardy, W. Ni, C. Woodcock, J.C. McKenzie, R. Jordan, and X. Li. 1997. Variation of snow cover ablation in the boreal forest: A sensitivity study on the effects of conifer canopy. Journal of Geophysical Research. 102(D24):29,389-29,395.

Hardy, J.P., R.E. Davis, and J.C. McKenzie. 1995. Snow Distribution Around Trees: Incorporation of snow interception patterns into spatially distributed snow models. Eos Transactions, AGU 1995 Fall Meeting, Abstract, p. 202.

Hardy, J.P., R.E. Davis, and R. Jordan. 1996. Snow melt modeling in the Boreal forest. Eos Transactions, AGU 1996 Fall Meeting, Abstract, p. 196.

Hardy, J.P., R.E. Davis, R. Jordan, X. Li, C. Woodcock, W. Ni, and J.C. McKenzie. 1997. Snow ablation modeling at the stand scale in a boreal jack pine forest. Journal of Geophysical Research. 102(D24): 29,397-29,405.

Hardy, J.P., R.E. Davis, R. Jordan, W. Ni and C. Woodcock, 1998. Snow ablation modelling in a mature aspen stand of the boreal forest. Hydrological Processes, 12 (10/11), p. 1763-1778.

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Ni, W., X. Li, C.E. Woodstock, J.L. Roujean, and R.E. Davis. 1997. Transmission of solar radiation in boreal conifer forests: Measurements and models. Journal of Geophysical Research.

102(D24):29,555-29,566.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

## 17.3 Archive/DBMS Usage Documentation None.

## 18. Glossary of Terms

None.

## 19. List of Acronyms

ASCII - American Standard Code for Information Interchange

BOREAS - BOReal Ecosystem-Atmosphere Study

BORIS - BOREAS Information System
CD-ROM - Compact Disk-Read-Only Memory

CGR - Certified by Group

CPI - Certified by Principal Investigator

CPI-??? - CPI but questionable

CRREL - Cold Regions Research and Engineering Laboratory

DAAC - Distributed Active Archive Center

EOS - Earth Observing System

EOSDIS - EOS Data and Information System

FFC-W - BOREAS Focused Field Campaign - Winter

FOV - Field of View

GIS - Geographic Information System

GMT - Greenwich Mean Time

GSFC - Goddard Space Flight Center

HTML - Hyper-Text Markup Language

HYD - Hydrology IR - Infrared

NAD83 - North American Datum of 1983

NASA - National Aeronautics and Space Administration

NSA - Northern Study Area

OA - Old Aspen

OBS - Old Black Spruce OJP - Old Jack Pine

ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park
PIR - Precision Infrared Radiometer

PRE - Preliminary

RH - relative humidity

SRC - Saskatchewan Research Council

SSA - Southern Study Area

temp - Temperature
TF - Tower Flux

URL - Uniform Resource Locator

## 20. Document Information

## 20.1 Document Revision Dates

Written: 24-Mar-1997 Revised: 06-May-1999

## 20.2 Document Review Dates

BORIS Review: 12-Jan-1998 Science Review: 15-Jul-1997

#### 20.3 Document ID

#### 20.4 Citation

When using these data, please include the following acknowledgment and cite the following papers:

The BOREAS HYD-03 subcanopy meteorological data were collected and processed by Janet P. Hardy and Robert E. Davis of US Army CRREL. Their efforts in making these data available are greatly appreciated.

Davis, R.E., J. P. Hardy, W. Ni, C. Woodcock, C.J. McKenzie, R. Jordan and X. Li, 1997. Variation of snow cover ablation in the boreal forest: A sensitivity study on the effects of conifer canopy. J. of Geophys. Res., 102 (N<sub>2</sub>4), 29,389-29,396, December 26, 1997.

Hardy, J.P., R.E. Davis, R. Jordan, W. Ni and C. Woodcock, 1998. Snow ablation modelling in a mature aspen stand of the boreal forest. Hydrological Processes, 12 (10/11), p. 1763-1778.

Hardy, J.P., R.E. Davis, R. Jordan, X. Li, C. Woodcock, W. Ni and J.C. McKenzie, 1997. Snow ablation modeling at the stand scale in a boreal jack pine forest., J. of Geophys. Res., 102 (N24), 29,397-29,406, December 26, 1997.

If using data from the BOREAS CD-ROM series, also reference the data as:

R.E. Davis, "Distributed Energy Transfer Modeling in Snow and Soil for Boreal Ecosystems." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

## Also, cite the BOREAS CD-ROM set as:

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

## 20.5 Document Curator

## 20.6 Document URL

## REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE July 2000	3. REPORT TYPE AND DATES COVERED Technical Memorandum		
4. TITLE AND SUBTITLE  Technical Report Series on the Bo BOREAS HYD-3 Subcanopy	•	• •	5. FUNDING NUMBERS  923	
6. AUTHOR(S) Janet P. Hardy and Robert E. Forrest G. Hall and David E.			RTOP: 923-462-33-01	
7. PERFORMING ORGANIZATION NAME Goddard Space Flight Center Greenbelt, Maryland 20771	E(S) AND ADDRESS (ES)		8. PEFORMING ORGANIZATION REPORT NUMBER  2000-03136-0	
9. SPONSORING / MONITORING AGE National Aeronautics and Space Washington, DC 20546-0001		S (ES)	10. SPONSORING / MONITORING AGENCY REPORT NUMBER  TM—2000–209891  Vol. 23	
11. SUPPLEMENTARY NOTES J.P. Hardy and R.E. Davis: U D.E. Knapp: Raytheon ITSS	.S. Army Cold Regions I	Research and Engi	neering Laboratory (CRREL);	
12a. DISTRIBUTION / AVAILABILITY STA Unclassified—Unlimited Subject Category: 43 Report available from the NASA 7121 Standard Drive, Hanover,	A Center for AeroSpace In		12b. DISTRIBUTION CODE	

#### 13. ABSTRACT (Maximum 200 words)

The BOREAS HYD-3 team collected several data sets related to the hydrology of forested areas. This data set includes measurements of wind speed and direction; air temperature; relative humidity; and canopy, trunk, and snow surface temperatures within three forest types. The data were collected in the SSA-OJP (1994) and SSA-OBS and SSA-OA (1996). Measurements were taken for 3 days in 1994 and 4 days at each site in 1996. These measurements were intended to be short term to allow the relationship between subcanopy measurements and those collected above the forest canopy to be determined. The subcanopy estimates of wind speed were used in a snow melt model to help predict the timing of snow ablation. The data are available in tabular ASCII files.

BOREAS, hydrology, subcanopy meaurements.			15. NUMBER OF PAGES 18 16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT $UL$